GLAST Mission Update

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Project Scientist
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Structure and Evolution of the Universe Subcommittee (SEUS)
NASA Headquarters
July 2, 2003

http://glast.gsfc.nasa.gov

Office of Science
U.S. Department of Energy

Credits: Grady, Michelson, Ritz and Gehrels

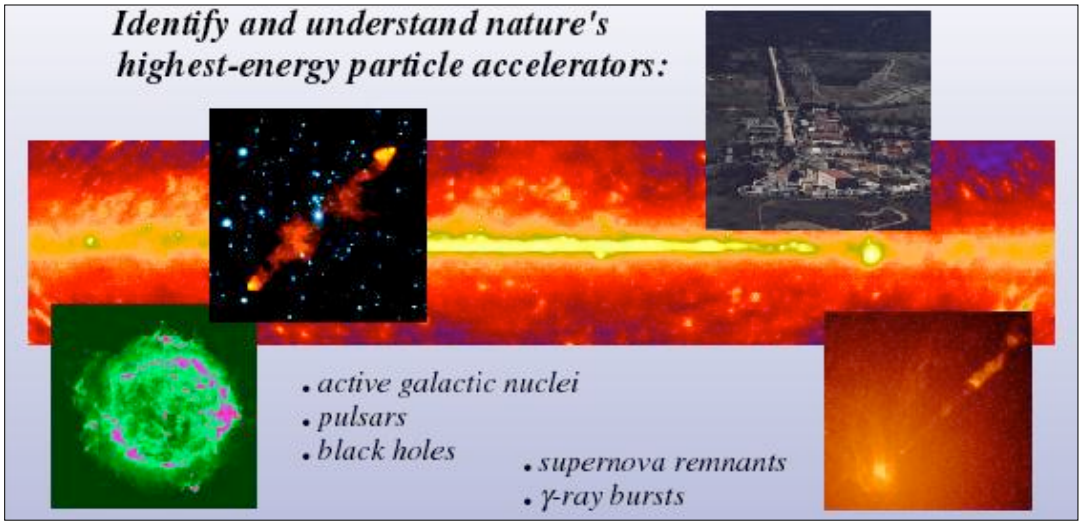

GLAST
http://glast.gsfc.nasa.gov
Exploring the High Energy Universe
NASA
Office of Science

Gamma-ray Large Area Space Telescope

Theme: Exploring Sites of Particle Acceleration in the Universe

- **Gamma Ray Large Area Space Telescope**
- **Launch in 2006**
- **4500 kg**
- **LAT instrument**
  20 MeV to 300 GeV
- **GBM instrument**
  10 keV to 25 MeV
- **http://glast.gsfc.nasa.gov/**

Mission Objectives



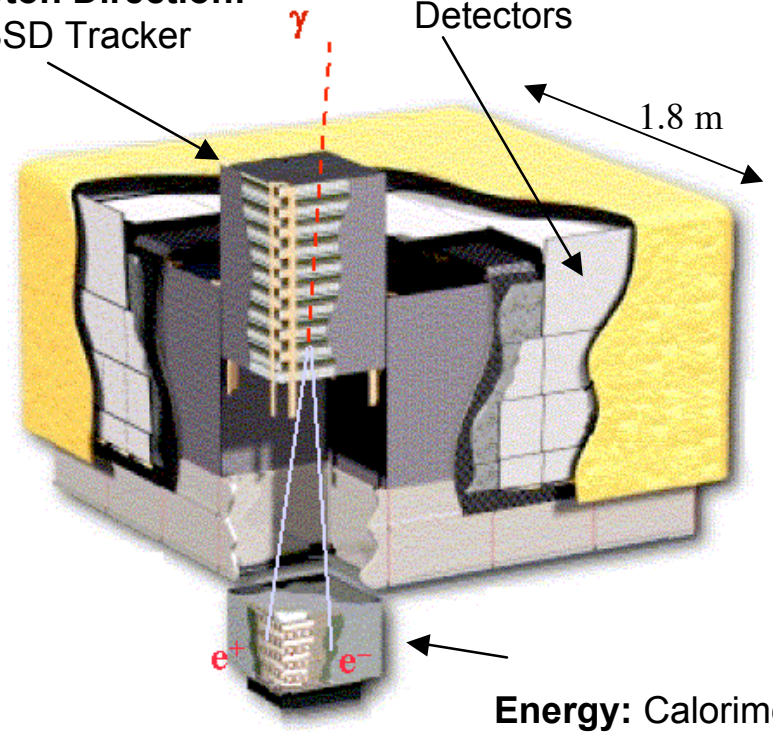
- Understand the mechanisms of particle acceleration in astrophysical environments such as active galactic nuclei, pulsars and supernova remnants
- Determine the high energy behavior of gamma-ray bursts and other transients
- Resolve and identify point sources with known objects
- Probe dark matter and the extra-galactic background light in the early universe

GLAST Instruments

Large Area Telescope (LAT)
PI: Peter Michelson
Stanford University

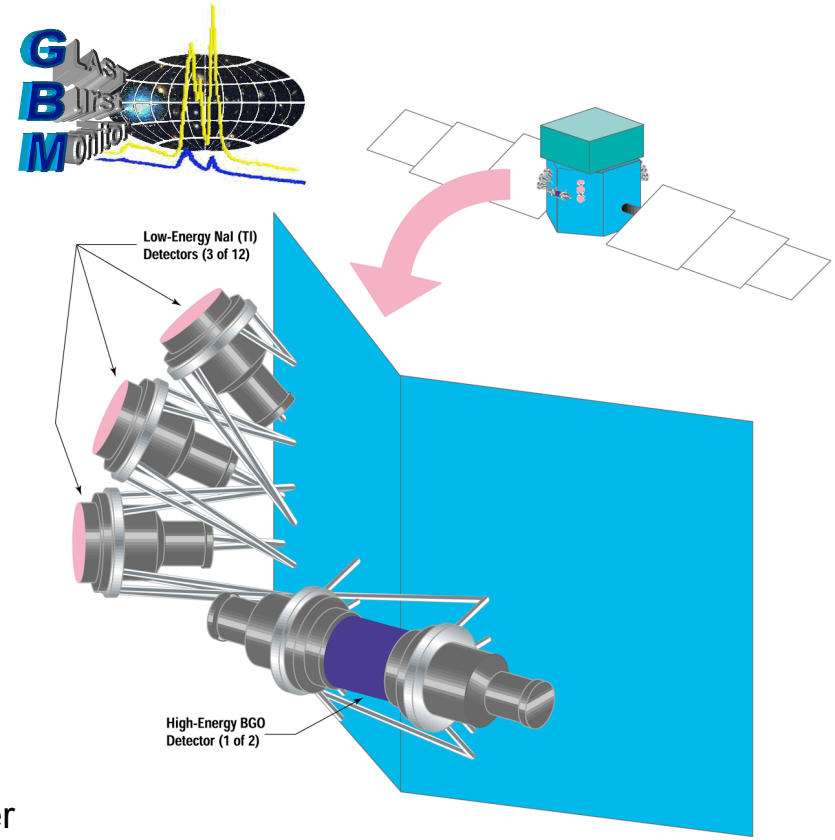
Photon Direction:
Si SSD Tracker

Background rejection:
Anti-coincidence
Detectors



Energy: Calorimeter

GLAST Burst Monitor (GBM)
PI: Charles Meegan
Marshall Space Flight Center



GLAST is an International Mission

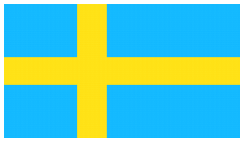
NASA - DoE Partnership on LAT

LAT is being built by an international team

- Si Tracker: Stanford, UCSC, Japan, Italy
- CsI Calorimeter: NRL, France, Sweden
- Anticoincidence: GSFC
- Data Acquisition System: Stanford, NRL

GBM is being built by US and Germany

- Detectors: MPE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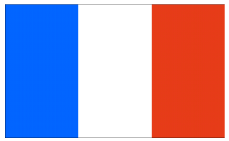
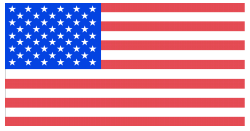
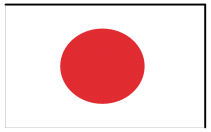
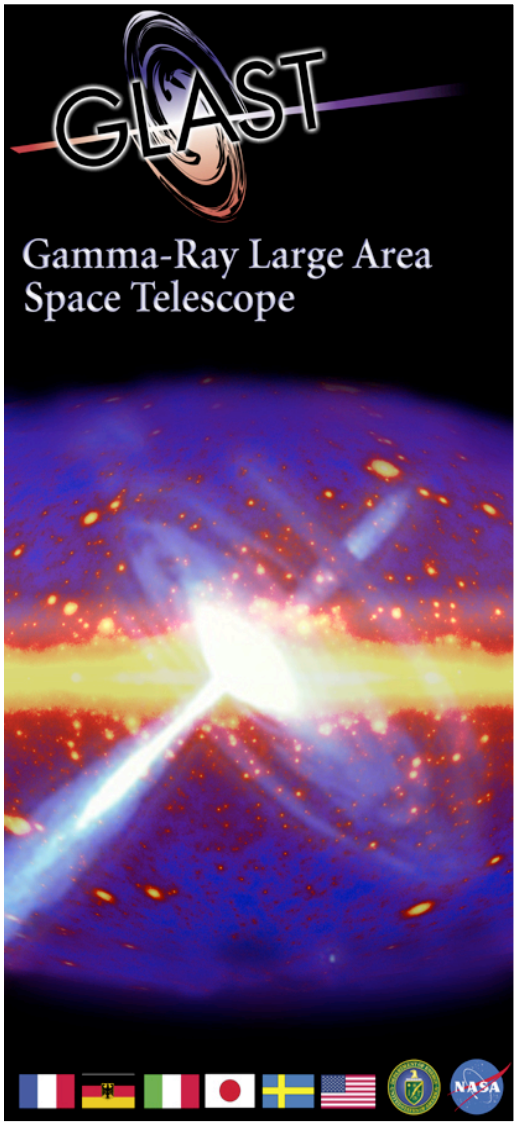
Italy


France

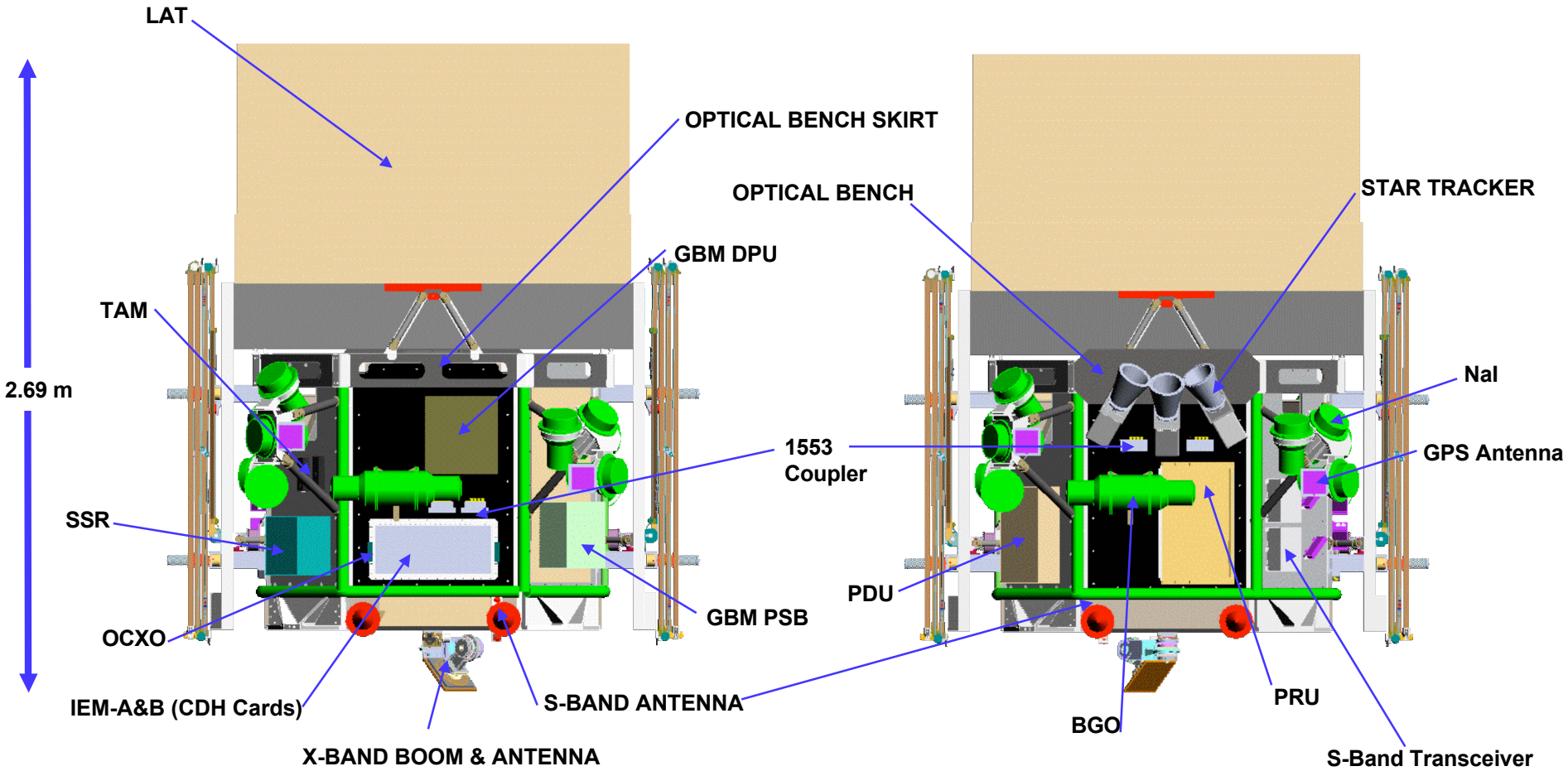

Germany


USA


Japan

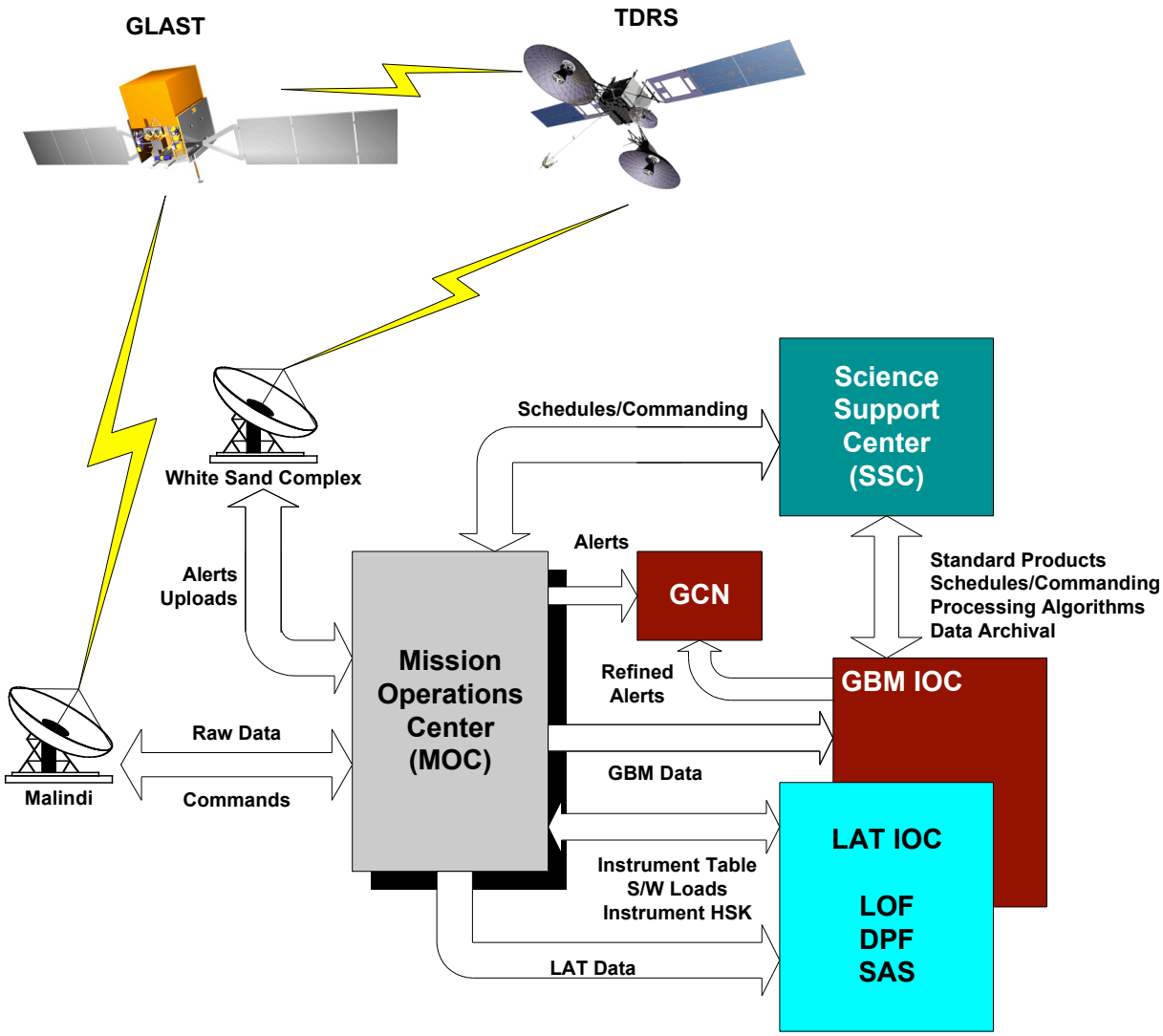


Spacecraft Views



* Provided by Spaectrum Astro

GLAST Data Flow Overview

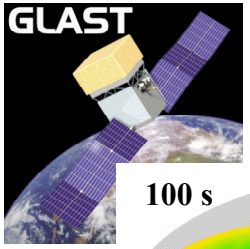


Key System Margins

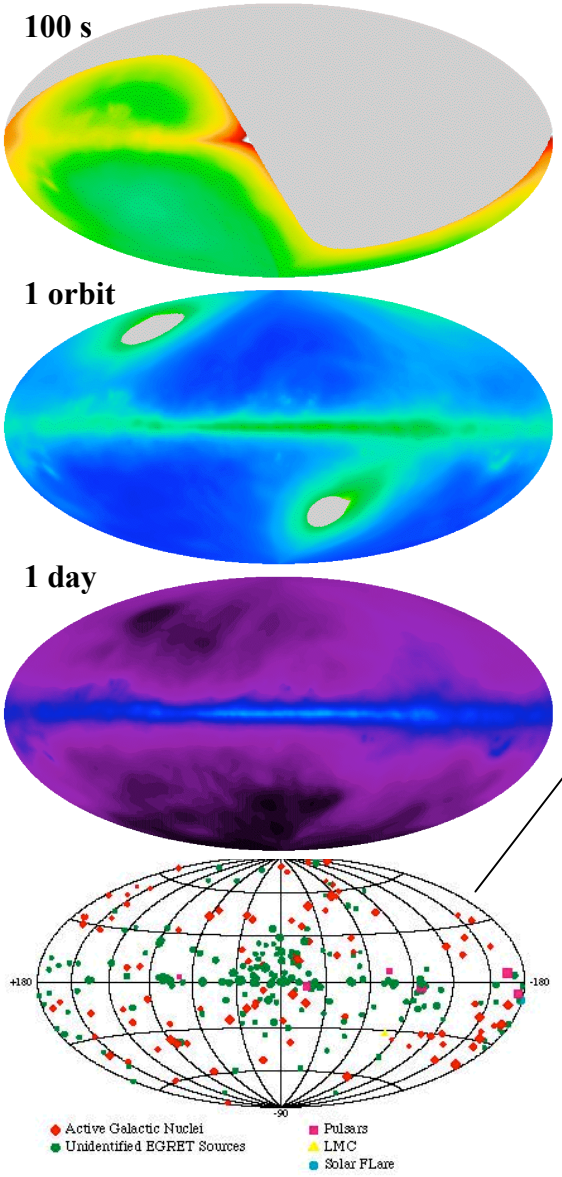
TPM	Requirement	Estimate	Margin
Observatory Mass (kg)	≤ 4627	4014	15%
Observatory Axial Center of Gravity (m)	≤ 1.59	1.34	0.25
Observatory (Eng/Sky Survey Mode) Orbit Average Power (W)	≤ 1700	1441	18%
LAT Pointing Knowledge (arcsec)	≤ 10.0	6.9	1.4x
GBM Pointing Knowledge (arcmin)	≤ 6.0	3.7	1.6x
Data Storage Capacity (Gbits)	>46.45	96 (BOL)	107%
Observatory Lateral Frequency (Hz)	>12	15.5	29%

NOTE: The Performance Estimate values are expressed as the CBE – Current Best Estimate

BOL: Beginning of Life



LAT Sensitivity



200 bursts per year

- prompt emission sampled to > 20 μs

AGN flares > 2 month

- time profile + E/E physics of jets and acceleration

bursts delayed emission

all 3EG sources + 80 new in 2 days

- periodicity searches (pulsars & X-ray binaries)
- pulsar beam & emission vs. luminosity, age, B

5-10 thousand sources in 1-yr survey

- AGN: logN-logS, duty cycle, emission vs. type, redshift, aspect angle
- extragalactic background light (+ IR-opt)
- new sources (μQSO,external galaxies,clusters)

LAT Requirements Summary

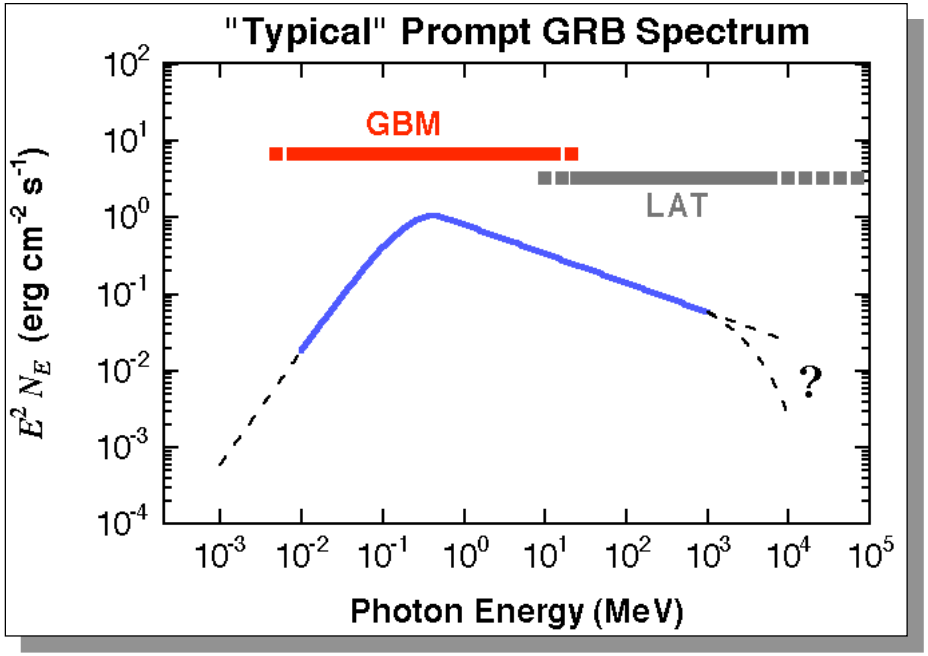
LAT science performance will meet or exceed requirements in GLAST Science Requirements Document (433-SRD-0001)

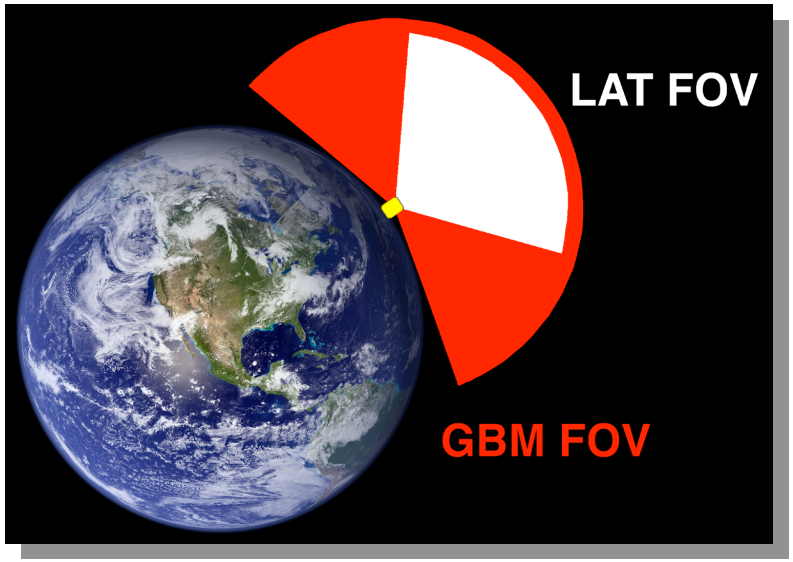
Parameter	SRD Value	LAT Performance
Peak Effective Area (in range 1-10 GeV)	**>8000 cm^2**	**10,000 cm^2 at 10 GeV**
Energy Resolution 100 MeV on-axis	**<10%**	**9%**
Energy Resolution 10 GeV on-axis	**<10%**	**8%**
Energy Resolution 10-300 GeV on-axis	**<20%**	**<15%**
Energy Resolution 10-300 GeV off-axis (>60º)	**<6%**	**<4.5%**
PSF 68% 100 MeV on-axis	**<3.5°**	**3.37° (front), 4.64° (total)**
PSF 68% 10 GeV on-axis	**<0.15°**	**0.086° (front), 0.115° (total)**
PSF 95/68 ratio	**<3**	**2.1 front, 2.6 back (100 MeV)**
PSF 55º/normal ratio	**<1.7**	**1.6**
Field of View	**>2sr**	**2.4 sr**
Background rejection (E>100 MeV)	**<10% diffuse**	**6% diffuse (adjustable)**
Point Source Sensitivity(>100MeV)	**<6×10^{-9} $cm^{-2}s^{-1}$**	**3×10^{-9} $cm^{-2}s^{-1}$**
Source Location Determination	**<0.5 arcmin**	**<0.4 arcmin (ignoring BACK info)**
GRB localization	**<10 arcmin**	**5 arcmin (ignoring BACK info)**

GLAST Burst Monitoring

LAT and GBM work synergistically to make new GRB observations

- **GBM provides low-energy context measurements with high time resolution**
  - Broad-band spectral sensitivity
  - Contemporaneous low-energy & high-energy measurements
  - Continuity with current GRB knowledge-base (GRO-BATSE)





- **Provides rapid GRB timing & location triggers w/FoV > LAT FoV**
  - Improved sensitivity and response time for weak bursts
  - Follow particularly interesting bursts for afterglow observations
  - Provide rapid locations for ground/space follow-up

GBM Capabilities

	BATSE	GBM - Requirement	GBM - Current Design
Energy Range	25 keV – 10 MeV	<10 keV – >25 MeV	6 keV - 30 MeV
Field of View	All sky not occulted by Earth	>8 sr	8.7 sr
Energy Resolution	<10%	<10% (0.1-1.0 MeV, 1 on-axis)	7% (100 keV) 5% (1 MeV)
Deadtime		< 10 s/event	2.5 s/event
Burst Sensitivity - Ground (5, 50-300 keV)	0.2 cm^{-2} s^{-1}	<0.5 cm^{-2} s^{-1}	0.45 cm^{-2} s^{-1}
Burst Sensitivity - On-board (5, 50-300 keV, 50% efficiency)		<1.0 cm^{-2} s^{-1}	0.78 cm^{-2} s^{-1}
GRB Alert Location	~25°	-	<15°
GRB Final Location	1.7°	-	<1.5°
GRB Notification Time to Spacecraft		<2s	2s (arbitrarily selectable, trade-off between speed & accuracy)

RECENT PROGRESS

- **Conducted extensive LAT CDR subsystem peer reviews (January through March 2003)**
- **Conducted Spacecraft PDR and Flight Software PDR.**
  - **Review team summary was quite favorable.**
  - **Both the Code 300 and the HQ Independent Review Team reviewed the design and development plans.**
  - **43 Spacecraft RFAs and 10 recommendations.**
  - **14 Flight Software RFAs.**
- **Conducted LAT CDR/CD-3 Review May 12-16.**
  - **LAT baseline schedule found to be in doubt.**
  - **3 mechanical/thermal technical issues identified.**
  - **35 RFAs.**
- **Completed first phase of the Ku Band Study. Second phase nearing completion.**
- **Construction continuing ahead of schedule for Spectrum Astro's new integration and test facility: "Factory of the Future"**
- **Delivered first spacecraft interface simulator to GBM team.**

RECENT PROGRESS (cont.)

- ***Completed GSFC orbital debris analysis***
  - ***Results indicated that the GLAST debris casualty area was below the threshold for controlled re-entry (ie, the propulsion system could be removed)***
  - ***Formal analysis at JSC in process. This will be the basis as to how the Project proceeds.***
- ***Significant progress made on instrument to spacecraft ICDs***
- ***Signed IV&V agreement for LAT Flight Software and spacecraft assessment.***
- ***Preparations in process for upcoming GLAST Ground System SRR***

RECENT PROGRESS (cont.)

- **Conducted GLAST Mission Preliminary Design Review and Non-Advocate Review.**
  - **Presented technical and programmatic status of the GLASTmission.**
  - **Reviewed by two review teams:**
    - **Code 300 Review Team assessment was the Project adequately demonstrated that the preliminary design addresses systems requirements with acceptable levels of risk, suitable trade studies have been conducted, interfaces have been identified, and verification methods have been satisfactorily described. The PDR successfully established basis for proceeding with the detailed design. 14 RFAs received**
    - **HQ Independent Review Team preliminary findings concluded that there are no impediments to proceeding with mission confirmation. Preliminary feedback included 17 findings and several concerns/recommendations for Project consideration.**
  - **The Project will continue to work the actions and complete the necessary documentation prior to the remaining confirmation reviews.**

GLAST Burst Monitor Funding

- **Funding from the German ministry to DLR was delayed earlier this year**
  - Funding finally approved at the end of April
  - Four months of schedule float were lost for the delivery of the detector and the power supplies
- **The overall schedule float for GBM is minimally adequate**
  - Sufficient to handle typical I&T workarounds, but not major issues
  - Delivery of the German elements will be the pacing hardware
- **The contract with MPE/DJO should be signed this week**
- **Funding was approved for the entire GBM program, closing this issue for the GBM team**
- **The GBM electronics and flight software CDR is scheduled for early August this year**
- **The instrument system CDR is schedule for January 2004**

LAT Calorimeter: Loss of CNES Funding

- **CNES informed the LAT collaboration at the end of April that funding would not be available to process the crystal detector elements (CDE) for the LAT calorimeters**
  - Prior to the decision to withdrawal funding, the schedule to award a contract in France to process the CDEs had eroded
- **The Project made decision to immediately begin the process to process the CDEs in the US**
  - A risk reduction activity had previously been implemented to have the capability to process the CDEs in the US
    - Reorganizing the responsibilities and getting the new activities in the US.
    - Revised MoA with IN2P3 has been signed in France.
    - CDE bonding team in place at Swales. Test bonding has begun.
- **The impact to the schedule has been a loss of schedule float in the calorimeter delivery to LAT system I&T**
  - Result: Start of LAT I&T will be delayed 2 to 3 months
- **Project is continuing to assess options for pulling the start of I&T to the original date.**
  - The timely production of the first two production calorimeters will enable this. Risks are mitigated by the fact that the calorimeter engineering model is high fidelity and has successfully completed environmental testing

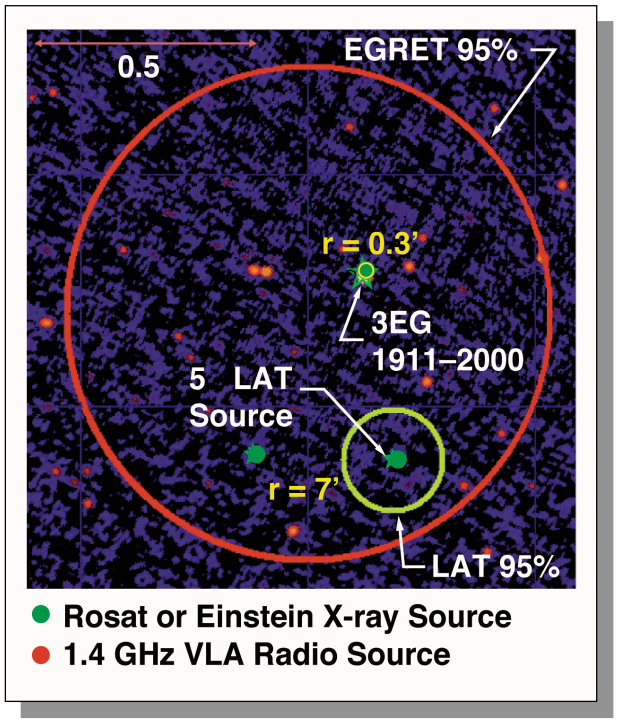
Trade Studies - Completed

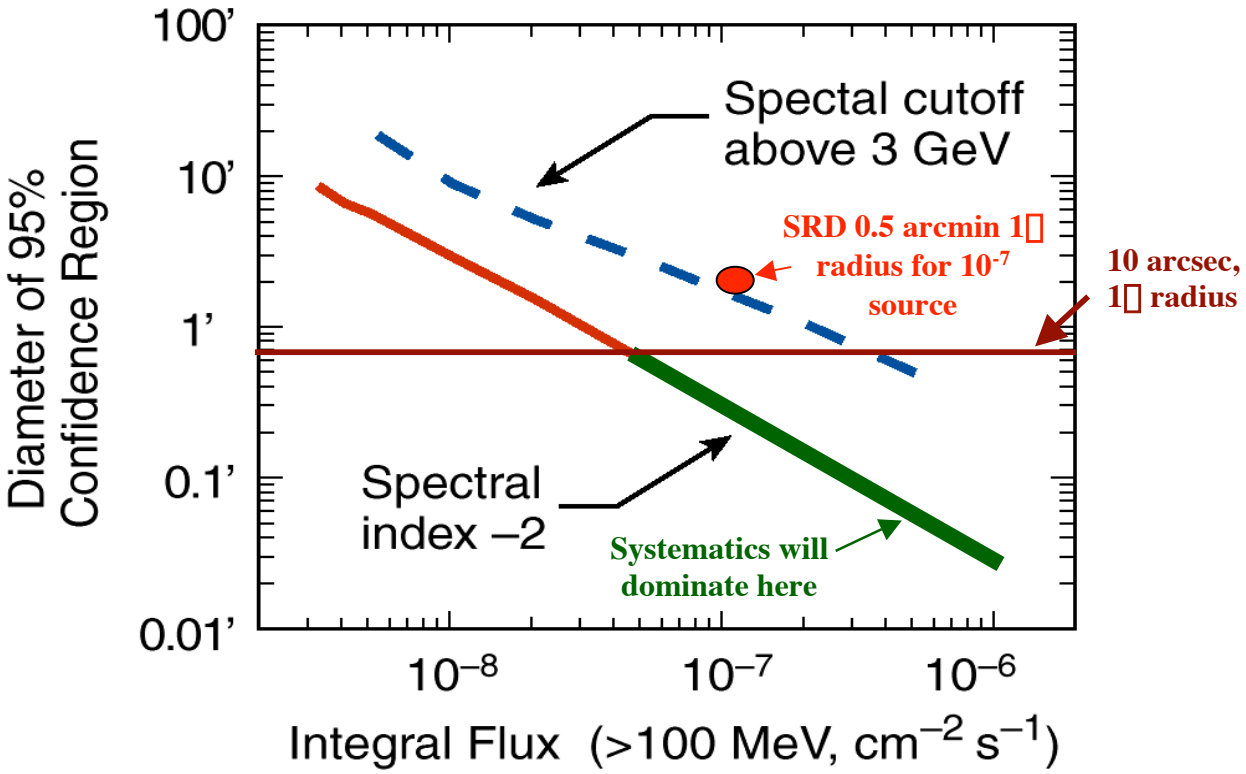
- **Completed Trades**
  - Delta II vs. Delta II heavy Launch Vehicle
    - Baselined heavy launch vehicle to provide greater lift capability
  - S-band downlink architecture
    - Selected interleaving real time and playback data on balanced 2.5Mbps I and Q channels
  - Orbit Altitude
    - Mission lifetime prediction less than 5 years at worst case launch dispersion and worst case solar cycle
    - CCR pending to change nominal orbit altitude to 565 km
- **In Process Trades**
  - Utilize Ku band SN link (TDRSS) for science data return
  - Based on results of JSC orbital debris analysis, determine whether GLAST can meet the design for demise criteria and avoid additional design complexity (ie, additional redundancy)

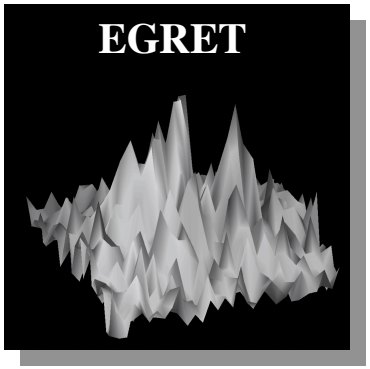
Other Issues

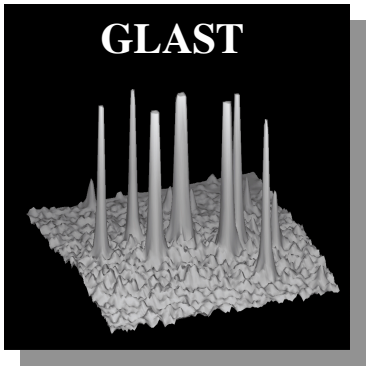
- **The INFN commitment to LAT is secure but agreement is not signed with ASI**
  - Funding for the Malindi ground station
    - Alternative data recovery plans being studies
  - ASI contribution to the tracker seems secure
- **Verification of the LAT pointing Knowledge**
- **ASIC chip development and testing**
- **Overall integration complexity**
  - Cost impact of a problem in thermal vacuum testing
  - Complete subsystem testing before integration
- **Calibration plans to be reviewed**
  - Bertsch, Atwood and Hermsen
- **Schedule very challenging**
  - LAT team moved calibration off critical path
  - Other minor schedule improvements being evaluated
  - Additional schedule margin being recommended by Grady et al.

LAT Source Localizations









Localization and Pointing Knowledge

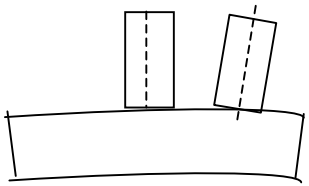
- **Pointing knowledge (<10 arcsec) vs. pointing accuracy (<2°)**
- **The uncertainty in the measured direction of a single photon by LAT is determined by:**
  - single photon PSF
  - end-to-end pointing knowledge
    - GN&C uncertainties
    - mechanical/thermal uncertainties
    - alignment calibration uncertainties
- **LAT will measure many photons from a point source. The point source localization is determined by a combination of several factors:**
  - Aeff, FOV, single photon direction errors, source characteristics (brightness, emission spectrum, sky region), and exposure

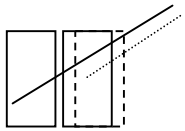
The requirements explicitly specify all of these.

Pointing knowledge

7 arcsec

- survey knowledge 1 arcsec
- grid bending 2 +/-1 arcsec
- Overall LAT dimension 2 +/-1 arcsec
- “transient” 5 +/-1 arcsec

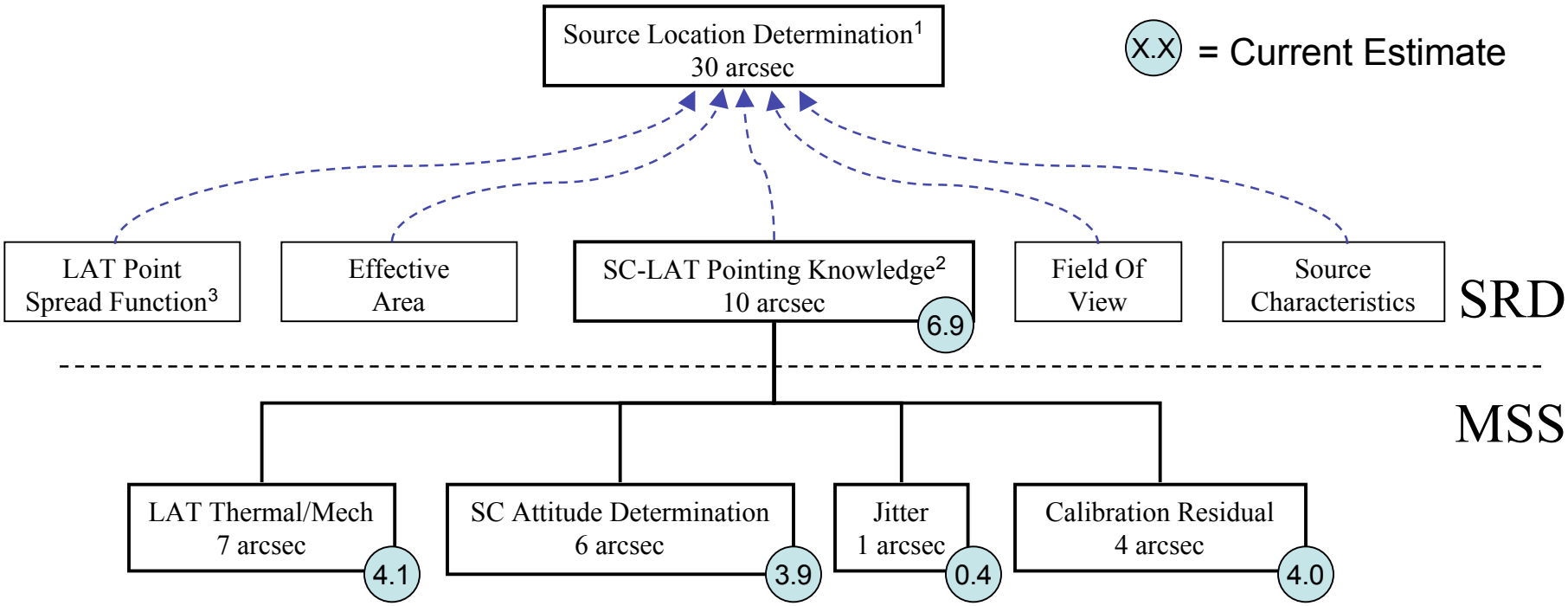




Orbital timescale (90 minutes)

Observatory Pointing Knowledge Components

- **GPO Systems Engineering is responsible for observatory verification with implementation by Spectrum Astro**
- **Decomposition of Science Requirement**



[1] High latitude source of 10^{-7} cm^{-2} s^{-1} flux at >100 MeV with a photon spectral index of -2.0 above a flat background and assuming no spectral cut-off. 1 sigma radius. 1-year survey.

[2] 1 sigma radial, over the life of the mission.

[3] Includes track reconstruction algorithms.

Potential GLAST Mission Descope Items

- Large Area Telescope
  - **Reduce number of towers (16 to 12)**
  - **Accept some out of spec trackers/calorimeters**
  - **Delete beam test on LAT Calibration Unit**
  - **Accept reduced redundancy in some of the ACD panels**
  - **Delete burst alert processing**
  - **Delete one of the EPUs**
- GLAST Burst Monitor
  - **Delete GBM from mission**
  - **Integrate and fly a reduced set of sensors if schedule or costs pressures evolve**
  - **Fly GBM hardware with reduced testing (instrument-level or satellite-level) if schedule or cost pressures evolve**
    - **No compromises on safety related testing**
- Science
  - **Delete interdisciplinary scientist funding**
  - **Descope guest observer program**

Potential GLAST Mission Descope Items

- Spacecraft
  - **Delete TDRSS S-band capability**
  - **Delete propulsion subsystem. Examine change to 7920 with unique PAF.**
  - **Delete one star tracker**
  - **Operate batteries at higher DOD and reduce size of solar array**
  - **Delete independent safe mode**
  - **Delete articulated X-band antenna. Relax requirement to not interrupt science during recorder dumps.**
  - **Delete autonomous burst alert re-pointing**
- Operations and data processing
  - **Reduce mission life to 2 years (minimum requirement)**
  - **Operate with fewer ground contacts and accept some data loss. No contingency contacts.**
  - **Delete Science Support Center and have IOCs provide data to high energy community**

Upcoming Project

- **Complete sequence of confirmation readiness reviews and confirmation reviews.**
- **LAT: Close-out mechanical/thermal CDR issues, complete responses to CDR RFAs and proceed with flight hardware fabrication.**
- **GBM: Complete subsystem and system CDRs.**
- **Spacecraft: Complete open trades, complete PDR RFA responses and hold subsystem CDR peer reviews.**
- **Award mission operations control center development contract.**
- **Conduct first launch vehicle interface working group meeting in August.**

Upcoming, cont.

- **Users Group being established**
  - Review the GLAST Data plan, transient release policy and the PDMP
- **LAT team meeting and SWG**
- **Italy, September 15-18**
  - Workshop on Diffuse Radiations
  - SWG (
    - face to face meetings every 6-9 months
    - phone meetings
- **Instrument deliveries in summer/fall of 2005**
  - Launch 2006
  - September (“God willin’ and the creek don’t rise.”)
    - 5 month slip recommended

GLAST Mission Profile

- **Mission Lifetime 5 years, Goal 10 years**
- **Observatory checkout 30-60 days**
- **First year is scanning**
  - Planned observations subject to interruption for extraordinary transients
- **Second year and beyond- scanning and/or pointing as driven by competitive proposals**
  - Observatory is designed to “point anywhere, anytime”
    - Operate without pointing at the Earth
    - Reorient quickly to follow a transient
  - 3 normal operational modes
    - Scan (baseline)
    - Inertial pointing
    - Scan pointing - takes advantage of the wide field of view to optimize time on sky

Guest Investigator Program

- **GI program starts during the survey**
  - 10-15 GIs
- **Will grow to ~100 Guest Investigations funded by NASA each year.**
- **GLAST Fellows program**

- **Continue Interdisciplinary Scientist (IDS) Program**
  - C. Dermer (NRL) - non-thermal universe
  - B. Dingus (Wisconsin) - transients
  - M. Pohl (Ruhr U.) - diffuse galactic
  - S. Thorsett (UCSC) - pulsars

- **Program of Education and Public Outreach continues throughout the mission**

Data release policies

- **All-sky survey during the first year.**
  - LAT team to produce a point source catalog and an all sky map; formal release 90 days following completion of the survey.
- **Transient source locations are made public immediately with photon data (light curves, improved positions, etc.) to follow as practical.**
  - During first year photon data to include warning that the data may be unverified and uncalibrated
  - Best efforts to release preliminary catalogs in time for AOs
    - The first 3 months of observations will be delivered at 6 months
    - The full 12 months of observations will be delivered 1 month after the end of the sky survey
- **Guest investigators may propose for source studies, associated theory or key projects**
  - Data from these sources of interest are made available immediately to the GIs.
- **Following the survey, it is being proposed that all GLAST data will be made public immediately.**
  - Comments on this policy may be sent to Jonathan.F.Ormes@nasa.gov or Donald.A.Kniffen@nasa.gov.
  - We plan to conduct workshops on how to propose for and how to the use the tools to analyze the GLAST data

Phase 1: LAT verification and sky survey

- **All-sky survey during the first year.**
  - LAT team to produce a point source catalog and an all sky map.
- **Transient source locations are made public immediately (i.e. on time scales consistent with the rise times of the transient) with photon data (light curves, improved positions, etc.) to follow within a few days.**
  - During first year photon data to include warning that the data may be unverified and uncalibrated
  - Best efforts to release preliminary catalogs in time for AOs
    - The first 3 months of observations will be delivered at 6 months
    - The full 12 months of observations will be delivered 1 month after the end of the sky survey
- **Guest investigators may propose for source studies, associated theory or key projects**
  - Data from these sources of interest are made available immediately to the GIs with warning.
- **Instrument verification using sources described in the LAT proposal**
- **Calibrated sky survey data to be released no later than 90 days following the completion of the one year sky survey.**
- **Operations to include following five to ten bright gamma-ray bursts**

Transient policy

- The GLAST instrument teams have the duty to release data on transient gamma ray sources to the community as soon as practical. The decisions on which data are to be released will be based on advice from scientists analyzing the data and an evaluation of the scientific interest that the data might generate. They will follow the general guidelines suggested below:
- 1) Gamma-ray bursts: All data on gamma-ray bursts that trigger either the LAT or GBM will be released. The prompt data release will include direction, fluence estimate and other key information about the burst immediately on discovery. Individual photon data and technical information for their analysis will be released as soon as practical.
- 2) Blazars and some other sources of high interest: 10-20 pre-selected sources from the 3rd EGRET catalog will be monitored continuously and the fluxes and spectral characteristics will be posted on a publicly accessible web site. Another 10-20 scientifically interesting sources will be added to this list during the survey. The list will include some known or newly discovered AGN selected to be of special interest by the TeV and other communities as well as galactic sources of special interest discovered during the survey.
- 3) New transients: The community will be notified when a newly discovered source goes above an adjustable flux level of about (2-5) x 10^{-6} photons (> 100 MeV) per cm^2 s for the first time; the flux level is to be adjusted to set the release rate to about 1-2 per week. A source exhibiting unusual behavior that is detectable on sub-day timescales, such as a spectral state change or a large flux derivative while the source is at elevated flux levels, will also trigger an alert to the community.

Multi-wavelength campaigns

- **Science requires broad band (radio to gamma-rays) study of these celestial sources. Therefore, following the survey, the observing program will be determined entirely by the astronomical and high energy physics communities based on proposals submitted.**
    - LAT and GBM team members can compete, but cannot win additional funding.
    - Non-US investigators may apply
    - Selection is based on peer reviewed proposals.
  - The community will interface to the GLAST data through the GLAST Science Support Center.
    - SSC mirror sites in Italy (LAT and GBM may have others)

http://glast.gsfc.nasa.gov/science/multi/

GLAST
Gamma-ray Large Area Space Telescope

Home Search Feedback

- News & Events
- General Public
- Science & Technical
- GLAST SSC
- Project Office
- Gnd Sys & Msn Ops
- Resources & Links

Multiwavelength Observations

- Gamma-ray Multiwavelength Mailing List Archive
  Please contact Dave Thompson or J.D. Myers to be added to the mailing list.
- Science Requirements Document
- Large Area Telescope (LAT) Properties
- GLAST Burst Monitor (GBM) Properties
- Planning, Operations, and Data Policies (from the NASA Announcement of Opportunity)
- Operations Concept Document
- Project Data Management Plan (in preparation)
- GLAST Science Support Center
- GLAST Telescope Network
- Multiwavelength Contacts: Dave Thompson, Steve Thorsett (Pulsars)

Need the plug-ing for reading PDF files? You can obtain it through Adobe.

News | Public | Science | SSC | Project | GSMO | Resources

NASA Science Official: Neil Gehrels
Responsible NASA Official: Phil Newman
Curator: J.D. Myers

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A service of the Laboratory for High Energy Astrophysics at Goddard Space Flight Center

Last modified: January 29, 2003

Science Analysis Software

- **Level 1 Processing (reconstructs events, e.g., finds photons)**
  - Prompt processing of Level 0 data
  - Near real time monitoring information to the LOF
  - Monitor and update instrument calibrations
- **Monte Carlo simulation of LAT**
- **Create high level science products**
  - Transient sources – prompt reporting
  - Point source catalogue
- **Interface with other sites (sharing data and analysis tools development)**
  - Mirror sites
  - Science Support Center at Goddard
- **Support Engineering Model and Calibration tests**
- **Support the LAT Collaboration tools**

Data Output from LAT Team Projects

From LAT Flight Proposal:

Table 2.1.4: All-Sky Survey Project

Data Product	Updates	Comments
Source Catalog	**Available and regularly updated on the web, with major publications after 1, 2, and 5 years**	**Includes significance, flux, spectra, locations, and identifications**
All-Sky Map	**1, 2, and 5 years**	**Intensity, counts, and exposure maps over various energy ranges**
Residual Maps	**1, 2, and 5 years**	**A residual map for each all-sky map after subtracting point sources and Galactic emission**
Diffuse Model	**Prelaunch, then update as necessary**	

Table 2.1.5: GRB and Transients Project

Data Product	Updates	Comments
GRB Catalog	**Monthly via WWW, with periodic refereed publications**	**Includes fluence, durations, time profiles, spectra, and locations**
Transient Alerts	**Continuous, on a timescale of days via WWW and IAU circulars for transients. Continuous, on a timescale of seconds for GRBs and via GCN.**	**GRBs and other transient alerts will include flux and locations. Flaring sources will include possible identifications**

In-depth Analyses of Selected Sources

Sources selected to:

- initiate team's science program;
- best evaluate instrument performance;
- improve all aspects of LAT data analysis & software, benefiting entire community

Analysis will:

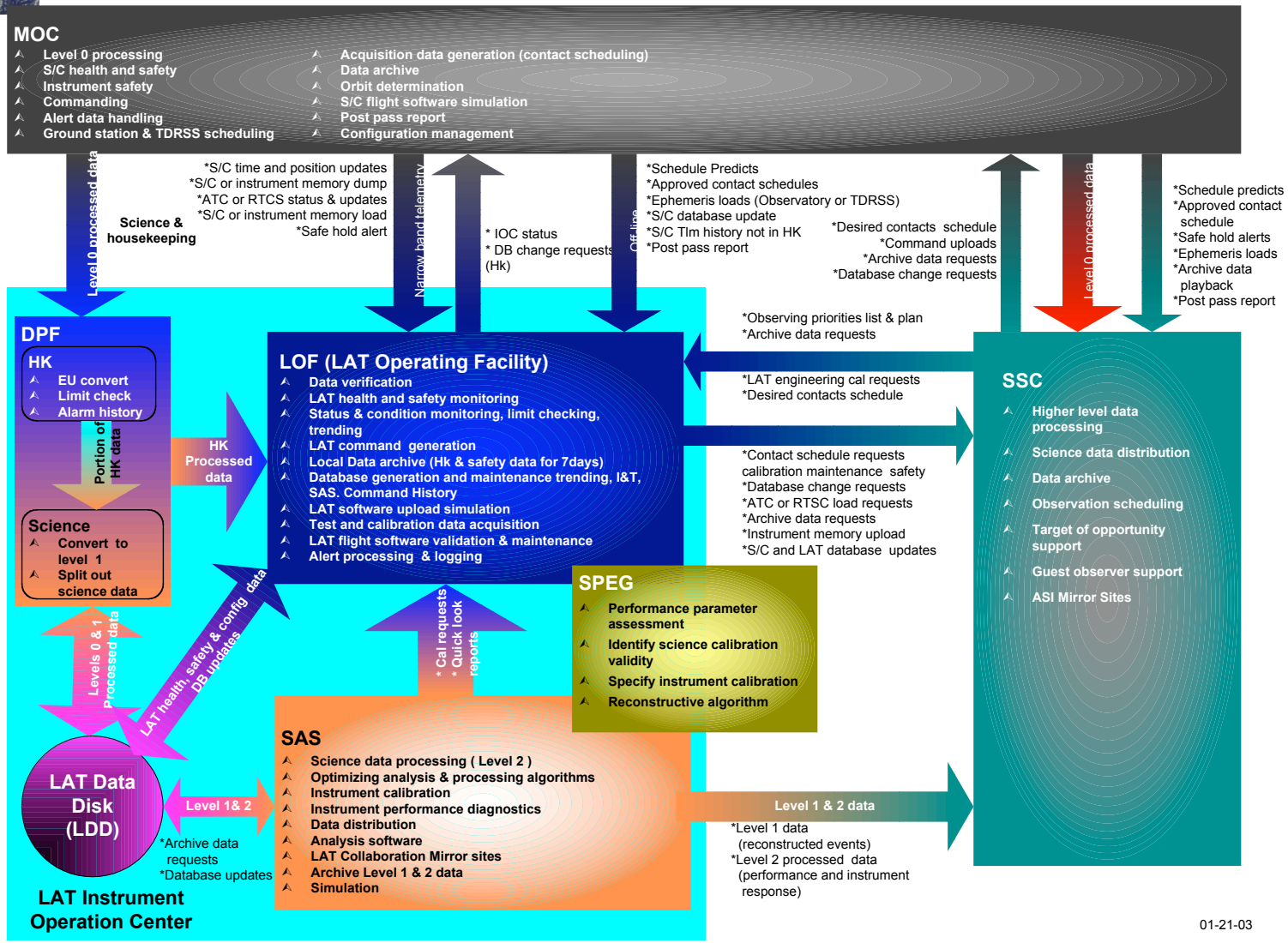
- use all-sky survey data and multiwavelength campaigns where applicable;
- take advantage of team's expertise, particularly in modelling the structured Galactic background to resolve extended sources

From LAT Flight Proposal:

Table 2.1.6: Selected Sources for In-depth Analyses

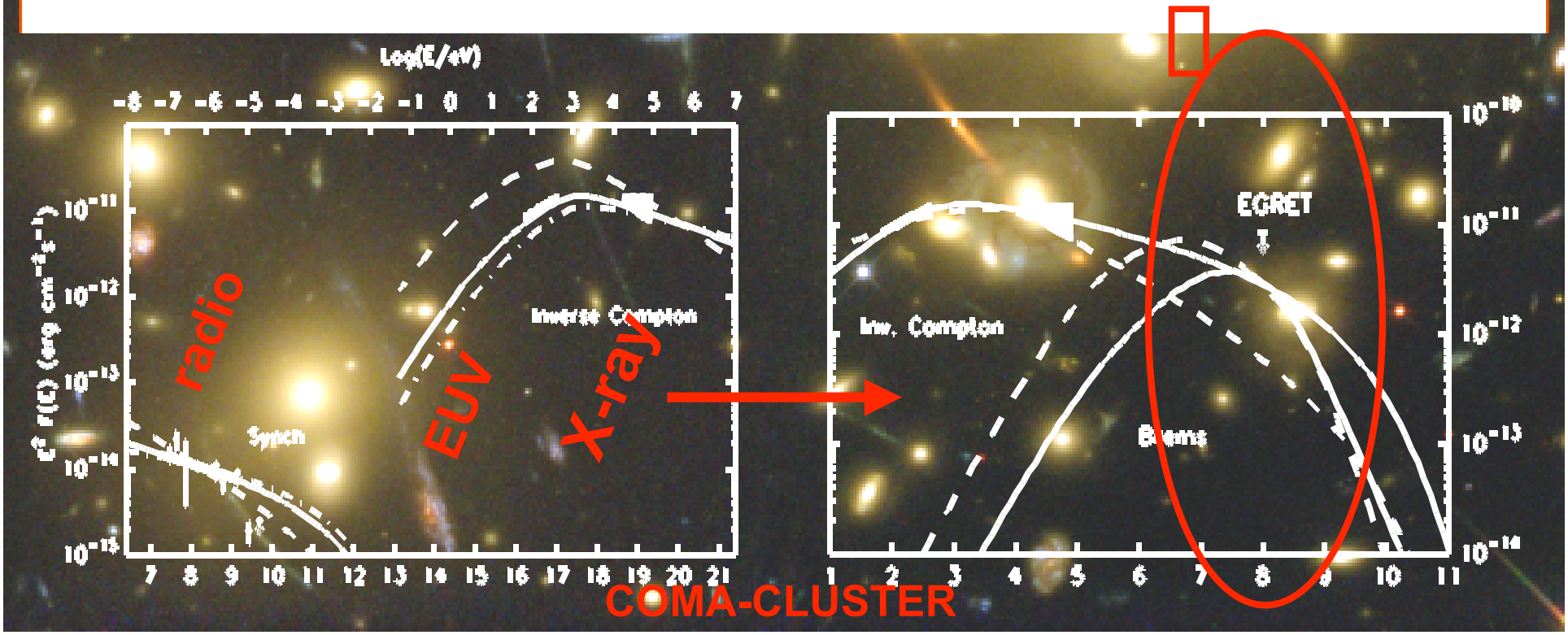
Sources	Characteristics	Science Goals
PARTICLE ACCELERATION in PULSARS and PLERIONS		
PSR 1951+32	EGRET pulsar, 39.5 ms, 100 kyr, 2.5 kpc, $B=10^{12}$ G,	Study phase-resolved spectra and test LAT absolute timing data and software; measure the cut-off energy E_{cut} above 10 GeV to extend the $E_{cut}(B)$ relation; spatially resolve its remnant CTB80 (∅=80')
PSR 1617-5055	Radio pulsar not seen by EGRET despite its 8th rank in E/D^2, 69 ms, 8 kyr, 6.5 kpc	Deeply search for pulsed emission to constrain the beaming fraction in γ rays vs. polar cap and outer gap predictions; search for DC emission from its remnant RCW103 (∅= 10')
PSR1853+01 plerion	267 ms, 20 kyr, 3.3 kpc, $B=2\ 10^{13}$ G, high E/D^2, in 3EG1856+0114 error box	Study DC emission from the X-ray/radio plerion; search for pulsed emission to extend the Ecut(B) relation to high field; spatially resolve the outer shell (Ω44: ∅ ~ 30')
COSMIC-RAY ACCELERATION in SUPERNOVA REMNANTS		
Cas A Kepler	SN II in ~1670, 2.8 kpc, ∅= 5' SN Ib in 1604, 4.4 kpc, ∅= 3'	Study young shocks in SN II and SN Ib environments: radio to TeV data to separate electron and nuclei emission; long-term monitoring to look for a compact star; higher density for Cas A & increased LAT sensitivity at b = 6.8° for Kepler
Cygnus Loop IC443	Sedov phase, 360 pc, 230'x160' Sedov phase, 1-2 kpc, ∅= 45', in 3EG 0617+2238 error box	Later SNR stage: spatially and spectrally resolve the nuclei emission; study non-linear acceleration; low Galactic background (b=8.5°) for Cyg Loop; enhanced nuclei emissivity expected where IC443 overtakes an H_2 cloud and X-ray and radio spectra harden
RX0852.0-4622 "Vela, Jr."	680 yr, ∅= 2.1°, closest SNR to Earth, 4.4° away from intense Vela pulsar	Observe using photons from Vela off-pulse time intervals to test source searches and localization in the wings of intense neighbors
NEARBY GALAXIES		
M31 LMC SMC	670 kpc, ∅~ 3° 55 kpc, ∅~ 8° 63 kpc, ∅~ 3°	Spatially and spectrally resolve their interstellar γ radiation to study cosmic rays, magnetic fields; compare energy balance and mass tracers in different metallicity environments
A 1656 Coma cluster	z = 0.02, ∅~ 1°	Constrain the energy density of cosmic rays inside a cluster; resolve the predicted emission above a low background (b= 89°); study the merging of two clusters
ACTIVE GALACTIC NUCLEI		
PKS0528+134 Mrk 501	EGRET flat spectrum quasar, z = 2.06 TeV BL Lac, z = 0.03	Multi-wavelength, multiyear monitoring to explore particle acceleration in blazar jets, in particular γ-ray spectral evolution from quiescent to flaring states
Cen A	Radio galaxy, z = 0.002, 3EG1324-4314	Confirm EGRET detection and study γ-ray emission from AGN jets at large viewing angles (>70°)
UNIDENTIFIED SOURCE REGIONS		
Rabbit region: l= 313° ±1° b= 0° ±1° Ω region: l= 17.5° ±1.6° b= -0.75°± 0.75°	3EG1420-6038 and 3EG1410-6147 3EG1826-1302 and 3EG1824-1514	Identify the γ-ray sources in complex regions and test source confusion limits; Rabbit: 2 SNRs, 1 candidate pulsar, 1 candidate plerion, and a few non-thermal shells Ω: 2 SNRs, PSR1823-13 (high E/D^2), and PSR1822-14
Galactic Center	l = 0° ±1°, b = 0° ±1° 3EG1746-285	Multi-year monitoring of the high-energy activity around SagA* and g-ray source localization with respect to the giant H2 clouds and to AXAF, XMM, and INTEGRAL sources
3EG1835+59	Brightest high-latitude, unid source, $E^{-1.7}$ spectrum	Search for a radio-quiet pulsar, test periodicity search software
GALACTIC SOURCES WITH RELATIVISTIC JETS		
GRS1915+105	Micro-quasar, 12.5 kpc jet velocity = 0.9.c	Search for predicted γ-ray emission from relativistic jets at large angles and compare to AGN emission; multi-year monitoring for flaring activity
SS433	5 kpc jet velocity = 0.3.c	Study termination shocks from jets impacting the remnant shell (120'x60') and producing non-thermal X-rays

LAT IOC Architecture



GALAXY CLUSTERS PROBED BY GAMMA-RAY ASTRONOMY

- Radio and X-ray detections of clusters imply the presence of nonthermal particles in the intracluster medium
- Origin of nonthermal particles is most likely cluster (or subcluster) mergers (e.g., Blasi & Petrosian) and accretion during structure formation
  - protons are essentially stored forever and reflect the merger and accretion histories of the clusters
- No individual cluster has been detected in γ-rays – yet
- Predictions about γ-fluxes range widely – possibly a large fraction of the extragalactic γ-flux (e.g. Waxman & Loeb)



GALAXY CLUSTERS PROBED BY GAMMA-RAY ASTRONOMY

The contribution from clusters to the high-energy □-ray background is uncertain and controversial!

- prospects are good for GLAST to resolve the controversy by establishing the □-ray nature of clusters and possibly resolving nearby clusters

BULK SOURCE OF UNIVERSE'S GAMMA RAYS IDENTIFIED, SCIENTISTS SAY

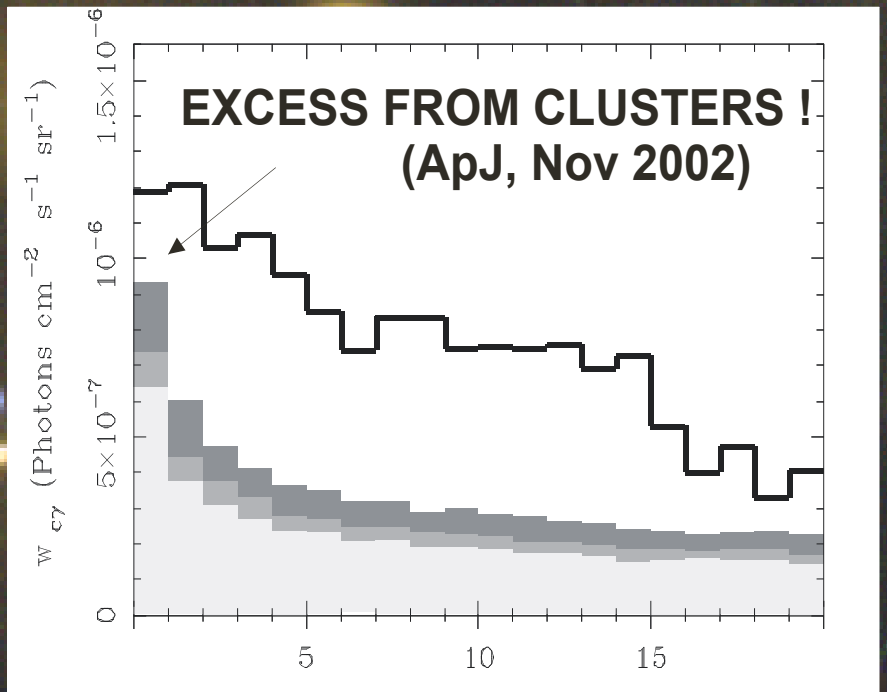
Scientists at Columbia University and Barnard College have found that the majority of the gamma rays outside of our galaxy are likely emitted by galaxy clusters and other massive structures [...]

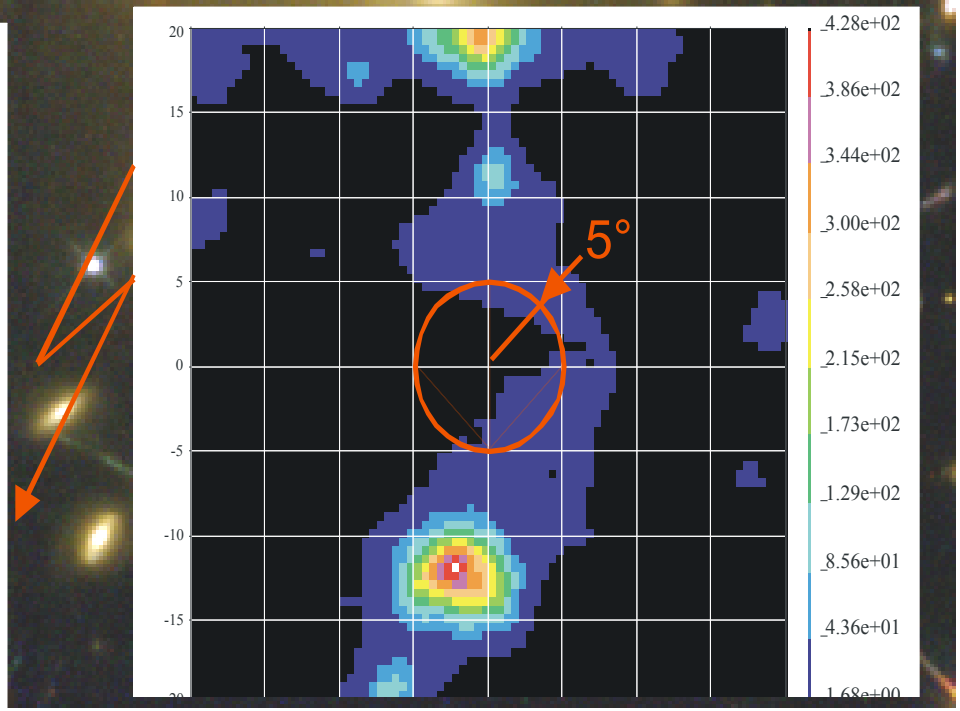
STILL NO DETECTION !

(ApJ, May 2003)

upper limit (E > 100 MeV):

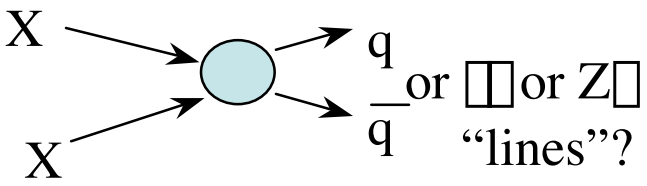
5.9×10^{-9} cm^{-2} s^{-1}

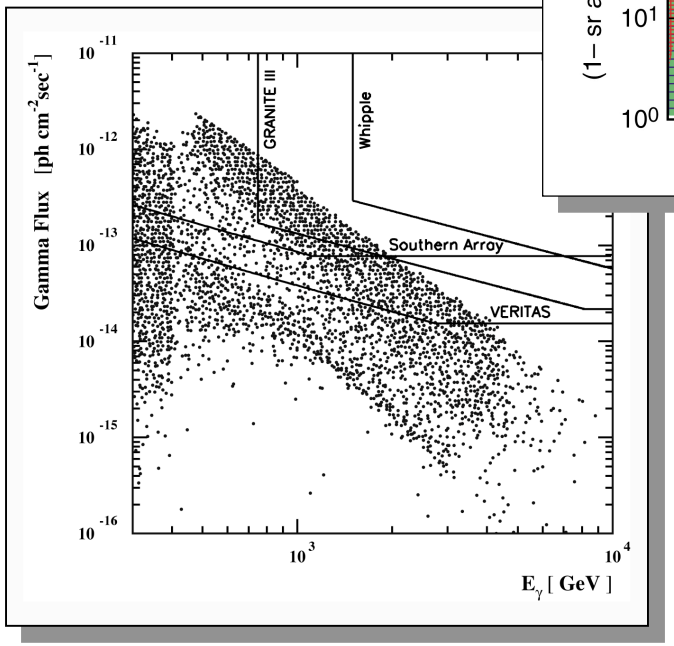


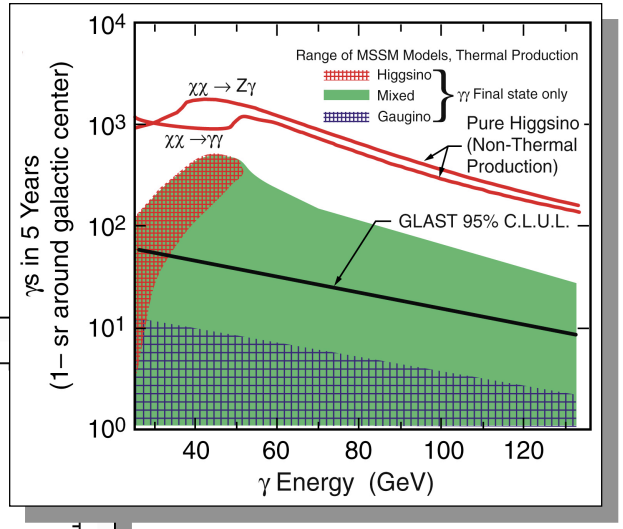


Searching for Dark Matter

- **The lightest super-symmetric particle c is a leading candidate for non-baryonic CDM**
- **It is neutral (hence neutralino) and stable if R-parity is not violated**
- **It self-annihilates in two ways:**
  - □□ → □□ where E□= M□ c²
  - □□ → □□ where E□= M□ c²(1□M_z²/4M□²)
- **Gamma-ray lines possible**
  - 30 GeV - 10 TeV

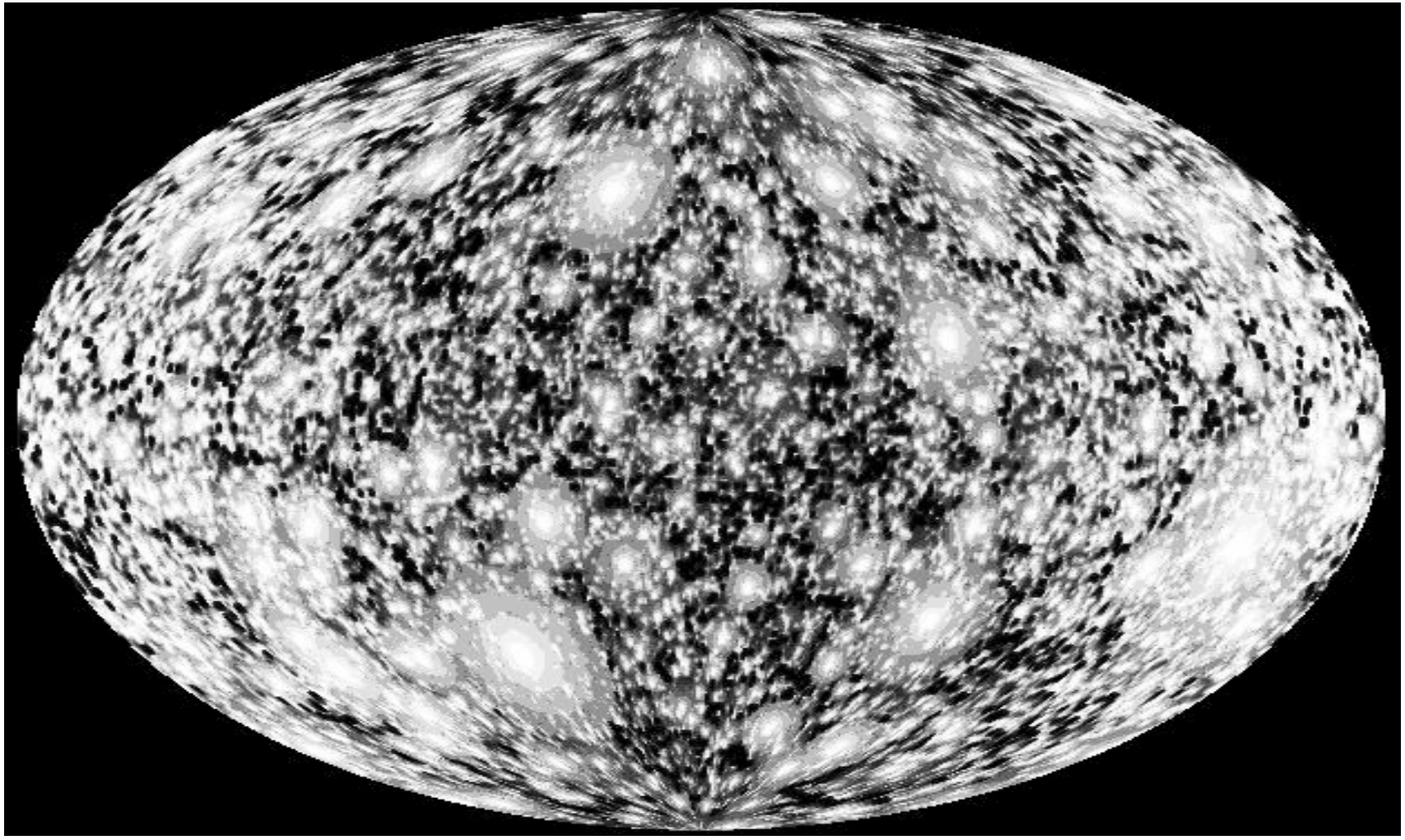






-rays from Dark Matter sub-halos

Credit: A. Olinto



- **Sky in Gamma-rays**

Aloisio, Blasi, AO '02

Project Organization

- Project Manager — K. Grady
- Deputy Project Manager — A.Vernacchio
- DPM/R — M. Seidleck
- Secretary — L. Barbour
- Project Scientist — J. Ormes
- Deputy Project Scientists — Steve Ritz/Neil Gehrels
- Science Working Group
- Financial Mgr. — L. Tall
  - Res Analyst vacant
- Contract Officer — J. Edmonds
- PSM — W. Hensley
  - CM J. Chipouras
  - Schedules M. Walsh
  - Library M. Rich
  - Data Mgmt/PS B. Townsend
- MOGS Mgr. — M. Rackley
  - MOC Mgr. — D. Small
    - Systems:
      - R. Cox
      - E. Canevari
      - B. Wagner
  - SSC Mgr. — J. Norris
    - Science Lead D. Band
- Flt Software — E.Andrews
  - vacant
- GBM Instrument Mgr. — B. Browne
  - Systems A. Whipple
- Launch Services Mgr. — M. Goeser
  - C. Mako (KSC)
- Observatory Mgr. — J. Bretthauer
  - Systems — A. Guha
- Systems Manager — J. Leibee
  - Mission Systems — N. Rioux
  - Systems:
    - M. Melton
    - T. Ford
    - C. Connor
    - B. Garnett
- LAT Instrument Mgr. — B. Graf
  - Systems — A. Whipple
  - On Site Sys. — J. Ku
  - ACD I/F — D. Mengers
- Sys Assurance Mgr. — R. Kolecki
  - QE — T. Alvarez
  - Parts — T. Perry
  - S/W QE — D. Harmon
  - Reliability — T. Di Venti
  - LAT On-site — T. Shepherd
  - S/C On-site — M. Kunda
- Safety Mgr. — D. Bogart
  - J. Anderson

Power – E. Gaddy	CDH – J. Sonsino
ACS – E. Stoneking	Communications – P. Acosta
Propulsion – M. Underdown	Thermal – L. Fantano
Electrical – F. Blanchette	Contamination – C. Lorentsen
Structures/Mechanism – S.Seipel, F. Tahmasebi, C. Fransen	I&T – E. Shippey

Original signed

Kevin Grady
GLAST Project Manager
June 1, 2003

LAT I&T, Verification, and Calibration Flow

TKR: QU FS from TKR fab

TKR: F1-2 from TKR fab

CAL: QU- FS from CAL fab

CAL: F1-2 from CAL fab

Elec: EM2 Elect. Modules, SIS

Calibration Unit - CU

I&T: Beam test CU – 4 towers
Cal

TKR/CAL: F1,2 from CU

Vibe	Random vibrate/sine sweep	Acc	Acceptance test level
Ac	Acoustic	QU	Qualification Unit
T-C	Thermal-cycle at 1 atmosphere	EM	Engineering Model
T-V	Thermal-vacuum cycle test	TM	Thermal model
EMI	Electro-magnetic interference test	CU	Calibration Unit
		FU	Flight Unit
	Calibration unit I&T	Cal	Calibration
	Flight unit/spares I&T	FS	Flight Spare

I & T Responsibility

Mech: Flt Grid from Mech

TKR: F3-16 from TKR fab

CAL: F3-16 from CAL fab

ACD: ACD to LAT I&T

Elec: Flt Elec. Mod. to LAT I&T

Flight LAT - FU

I&T: LAT Assembly, Test
Acc, Cal

I&T: LAT Functional, Thermal, Airborne cosmic E to E
Acc, Cal, T-C

Mech: Flt Rad's from Mech

Elec: SIU

I&T: LAT Environmental Tests Acc, Cal, T-V

Obs: Support Vibe/Ac
Acc

Obs: Support T-V
Acc

Obs: Support EMI
Acc

Guest Investigator Program

- **GLAST will have a robust Guest Investigator Program.**
  - Survey period: Some Guest Investigators (~dozen) will be selected to study previously known or suspected gamma-ray sources.
  - Science requires broad band (radio to gamma-rays) study of these celestial sources. Therefore, following the survey, the observing program will be determined entirely by the astronomical and high energy physics communities based on proposals submitted.
    - LAT and GBM team members can compete, but cannot win additional funding.
    - Non-US investigators may apply
    - Selection is based on peer reviewed proposals.
    - NASA to fund ~100 Guest Investigations each year.
  - The community will interface to the GLAST data through the GLAST Science Support Center.
    - SSC mirror sites in Italy (LAT and GBM may have others)